Asymmetries in electron emission produced by intense linearly and circularly polarized XUV radiation

A.N. Grum-Grzhimailo [1]

Skobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University, Moscow 119991, Russia

Synopsis Photoelectron angular distributions possess different kind of asymmetries, which reflect the dynamics of the process. Theoretical analysis of a few such asymmetries will be presented with reference to recent and possible future experiments at the XUV free-electron lasers.

Violation of certain symmetries often gives evidence to more complicated dynamics of the process than it is usually implied. The present talk concentrates on a few examples of such violation in the photoelectron angular distribution (PAD) generated by intense XUV radiation.

The first example is a forward-backward asymmetry in the PAD in ionization of positively charged ions. Such an asymmetry is caused by the contribution of higher multipoles of the electromagnetic field. This effect is known and has been extensively studied in ionization of neutral atoms and molecules by third generation synchrotron radiation sources (for example, [1]). With the advent of free-electron lasers it is now possible to observe the PADs, and hence the forward-backward asymmetry, in ionization of positively charged ions. The first results on the argon ion show the feasibility of such studies [2]. Furthermore, since the ion in the initial state is aligned, in certain cases a complete experiment with accounting for electric quadrupole (E2) amplitude becomes possible. To achieve this goal one has to incorporate data for both, linearly and circularly polarized radiation.

The second example is the PAD generated by bichromatic field with two multiple frequences. In particular, in contrast to the angle integrated cross section, the PADs are modified already when the radiation includes the fundamental (w) and its second harmonic ($2w$). Such a modification, i.e. the violation of the PAD's symmetry due to the interference between the amplitudes of the two possible ionization pathways, by the single $2w$-photon of the second harmonic and by the two w-photons of the fundamental, has been observed in the XUV only recently for linearly polarized light [3]. For optical lasers it has been observed long time ago and used to advantage for extracting relative amplitudes of photoionization into channels with different parity [4, 5].

For linearly and circularly polarized bichromatic fields the effect is different. In the former case one observes the violation of symmetry with respect to the plane perpendicular to the polarization vector of the radiation. The degree of this asymmetry depends on the strength of the fundamental and the harmonics. It shows an oscillatory behavior as function of the relative phase of the harmonics. For circularly polarized light the axial symmetry of the PAD is violated. A particular PAD depends on the frequency ratio between the two radiation beams, and whether they possess equal or opposite helicity. The general shape of the PAD follows the electric vector of the combined two-frequency field, which traces out a cycloid-like closed curve in a plane perpendicular to the direction of the radiation beam.

In addition, the asymmetries show resonance profiles as functions of the photon energy when passing through a resonance [6].

Examples of the asymmetries in the PAD will be presented for hydrogen, neon, argon.

References

[1] R. Guillemin, O. Hemmers, D.W. Lindle, S.T. Manson. 2006 *Rad. Phys. Chem.* **75** 2258

[2] G. Hartmann *et al.* 2016 Int. Conf. on Many Particle Spectroscopy of Atoms, Molecules, Clusters and Surfaces (Moscow, Russia, 23-26 August, 2016), Book of Abstracts, p.19

[3] K. C. Prince *et al.* 2016 *Nat. Photon.* **10** 176.

[4] N.B. Baranova *et al.* 1992 *Pisma Zh. Eksp. Teor. Fiz.* **55** 431 [*JETP Lett.* **55** 439 (1992)].

[5] Y.-Y. Yin, C. Chen, D.S. Elliott, A.V. Smith. 1992 *Phys. Rev. Lett.* **69** 2353; Z.-M. Wang, D.S. Elliott. 2001 *ibid.* **87** 173001.

[6] A.N. Grum-Grzhimailo *et al.* 2015 *Phys. Rev. A* **91** 063418; N. Douguet *et al.* 2016 *ibid.*, **93** 033402.

[1] E-mail: grum@sinp.msu.ru